



SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, TERUMI SUNAGA,  
a citizen of Japan residing at 8-26-5-103, Kounandai,  
Kounan-Ku, Yokohama-Shi, Kanagawa 234 Japan have  
invented certain new and useful improvements in

SPREAD SPECTRUM COMMUNICATION TRANSMITTER  
AND RECEIVER, AND CDMA MOBILE COMMUNICATION  
SYSTEM AND METHOD

of which the following is a specification:-

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1     TITLE OF THE INVENTION

SPREAD SPECTRUM COMMUNICATION TRANSMITTER  
AND RECEIVER, AND CDMA MOBILE COMMUNICATION SYSTEM AND  
METHOD

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BACKGROUND OF THE INVENTION

## 1.   Field of the Invention

                  The present invention relates to a CDMA  
(Code Division Multiple Access) mobile communication  
10   system and method using a spread spectrum  
communication system. Further, the present invention  
is concerned with a spread spectrum communication  
transmitter and receiver used for such a CDMA mobile  
communication system.

## 15           2.   Description of the Related Art

                  Fig. 1 is a block diagram of a base station  
transmitter used in a CDMA mobile communication system  
using a conventional spread spectrum communication  
system, which is typically described in the IS/95 that  
20   is a standard system in the U.S. Telecommunications  
Industry Association/Electronic Industries Association  
(TIA/EIA). Fig. 2 is a block diagram of a mobile  
station receiver in the CDMA mobile communication  
system.

25           The transmitter shown in Fig. 1 can  
simultaneously communicate with  $n$  mobile stations  
where  $n$  is an integer. More particularly, the  
transmitter includes traffic channel transmit units  
 $31_1$ ,  $31_2$ , ..., and  $31_n$ , which respectively communicate  
30   with the first, second, ..., and  $n$ th mobile stations.  
Each of the traffic channel transmit units  $31_1$  through  
 $31_n$  includes an information modulator 2 and a spread  
spectrum modulator 5. The information modulator 2 of  
each traffic channel modulates transmit data  
35   (information) 4 by a BPSK, QPSK or another modulation  
method. The modulated transmit data is applied to the  
spread spectrum modulator 5. The spread spectrum

1 modulators 5 of the traffic channel transmit units  $31_1$   
through  $31_n$  generate respective spreading codes (PN  
codes). The spread spectrum modulator 5 of each  
traffic channel spread the spectrum of the modulated  
5 transmit data from the information modulator 2.

The transmitter shown in Fig. 1 has a pilot  
channel transmit unit 30. The mobile receivers  
discriminate the base stations from each other by  
referring to the pilot channel. The pilot channel  
10 transmit unit 30 includes a pilot data generator 1, an  
information modulator 2 and a spread spectrum  
modulator 3. The information modulator 2 modulates  
pilot data generated by the pilot data generator 1 by  
the BPSK, QPSK or another modulation method. The  
15 spread spectrum modulator 3 spreads the spectrum of  
the modulated pilot data by using a spreading code  
specifically used for the pilot channel and different  
from the spreading codes used for the traffic  
channels. The pilot signal thus generated can be  
20 arbitrary data which can be known in the base stations  
and the mobile receivers. For example, data  
consisting of only binary ones or binary zeros can be  
used as the pilot data.

The output signals of the traffic channel  
25 transmit units  $31_1$  through  $31_n$  and the pilot channel  
transmit unit 30 are combined so that the pilot  
channel and the traffic channels are simultaneously  
transmitted in a given frequency band. Then, the  
combined radio signal is transmitted via an antenna.

30 Fig. 3 shows a relation between the pilot  
and traffic channels with respect to time. As shown  
in Fig. 3, the pilot signal is always transmitted  
without any interval. In this regard, the pilot  
signal is a continuous signal.

35 Referring to Fig. 2, the mobile receiver  
used in the conventional CDMA mobile communication  
system includes a pilot channel receive unit 34, and a

1 traffic channel receive unit 35. The pilot channel  
receive unit 34 includes a desreader 8, a path  
detector 11 and a hand-over controller 19. The  
traffic channel receive unit 35 includes despreaders 9  
5 and 10, a RAKE combiner 12, an information demodulator  
13, and a level measuring unit 14 for controlling a  
transmit power.

The desreader 8 performs a desreading  
process on the received signal by using the spreading  
10 code for the pilot channel. The despreaders 9 and 10  
perform a desreading process on the received signal  
by using the spreading code allocated to the receiver  
shown in Fig. 2 at the transmitter. The path detector  
11 detects multiple paths from the pilot signal. The  
15 hand-over controller 19 performs a hand-over control  
by using the results of the multipath detection  
obtained by the path detector 11. The output signal  
of the path detector 11 is also used as a timing  
signal used for the desreading process carried out by  
20 the despreaders 9 and 10. The RAKE combiner 12  
performs a RAKE process on the despread signals from  
the despreaders 9 and 10. The information demodulator  
13 demodulates the output signal of the RAKE combiner  
12 to thereby generate the original information. The  
25 level measuring unit 14 performs a level measuring  
operation for controlling the transmit power.

Fig. 4 shows a cell structure of the CDMA  
mobile communication system having the above  
transmitter and receiver. There are illustrated  
30 first, second, third and fourth base stations 21, 22,  
23 and 24, which cover service areas (cells) 26, 27,  
28 and 29, respectively. All the base stations 21  
through 24 have transmitters as shown in Fig. 1. A  
reference number 25 indicates a mobile receiver  
35 (station) having the structure shown in Fig. 2. The  
mobile station 25 is located within the cell 26  
covered by the base station 21, and can communicate

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1 with the base station 21.

Fig. 5 is a timing chart of timings at which the base stations 21 through 24 respectively transmit the pilot signal. In the conventional CDMA mobile communication system, all the base stations 21 through 24 employ the same spreading code for spreading the pilot data. The period of the spreading code used to spread the pilot data is sufficiently longer than one symbol time of information (data). As shown in Fig. 5, the base stations 21 through 24 transmit the same spreading code for the pilot channel with respective inherent offset times equal to a time  $t'$ . That is, the starting points of the spreading codes used in the base stations 21 through 25 are offset by the time  $t'$ .

The mobile station 25 shown in Fig. 4 receives the pilot signals from the base stations 21, 22, 23 and 24. Usually, the pilot signal from the base station 21 closet to the mobile station 25 has the strongest level. The despreader 8 of the pilot channel receive unit 34 shown in Fig. 2 performs the despreading process on the received signal by using the same spreading code as used in the transmitter.

Fig. 6A shows a correlation between the spreading code for the pilot channel and the pilot signal transmitted by the base station 21 and received by the mobile station 25. Similarly, Figs. 6B, 6C and 6D show correlations with the pilot signals transmitted by the base stations 22, 23 and 24 and received by the mobile station 25. Peaks 201 through 204 respectively shown in Figs. 6A through 6D indicate timing synchronization points in the pilot channels of the base stations 21 through 24. Variations in the waveforms other than the peaks 201 through 204 shown in Figs. 6A through 6D result from a self-correlation of the spreading code for the pilot channel. These variations in the waveforms are noise components for the mobile station 25 (receiver).

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1           The mobile station 25 shown in Fig. 4  
receives the signals of the pilot channels transmitted  
by the base stations 21 through 24 in such a state  
that the signals are superimposed. Hence, the output  
5   signal of the despreader 8 of the pilot channel  
receive unit 34 has a formation in which the four  
waveforms shown in Figs. 6A through 6D are  
superimposed. It should be noted that the  
correlations shown in Figs. 6A through 6D are not  
10   affected by multipath fading or Rayleigh fading.

          The path detector 11 shown in Fig. 2 detects  
the greatest peak in the output signal of the  
despreader 8 (the greatest peak in the superimposed  
correlation waveform). In the case of Fig. 4, the  
15   mobile station 25 is located within the cell 26 of the  
base station 21. Hence, the propagation distance  
between the base station 21 and the mobile station 25  
is shorter than the propagation distances from the  
base stations 22, 23 and 24. Hence, the path between  
20   the base station 21 and the mobile station 25 has the  
smallest propagation loss. Hence, the greatest peak  
in the despread received signal output by the  
despreader 8 corresponds to the correlation peak 201  
of the pilot channel of the base station 21 having the  
25   cell 26 in which the mobile station 25 is located.

          Since the pilot signals transmitted by the  
base stations 21 through 24 have respective inherent  
time offsets. Hence, by detecting the greatest peak  
of the superimposed correlation waveform, it is  
30   possible for the mobile station 25 to discriminate the  
base station 21 from the other base stations 22  
through 24 and detect the timing of spectrum-  
spreading. The path detector 11 informs the  
despreaders 9 and 10 of the traffic channel receive  
35   unit 35 of the timing of the greatest peak 201.

          The despreaders 9 and 10 perform the  
despreading processes on the received signal of the

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25                   However, the conventional CDMA mobile  
communication system thus configured has a  
disadvantage in that a good S/N ratio cannot be  
obtained at the time of receiving the pilot signals  
from the base stations due to the fact that all the  
30 base stations continue to transmit the pilot signals.  
The mobile station 25 shown receives the pilot signal  
from the base station 21 to which the mobile station  
25 belongs so that the signals of the pilot channels  
transmitted by the other base stations 22, 23 and 24  
35 are superimposed, as noise components, on the pilot  
channel data signal from the base station 21. Hence,  
the pilot channel receive unit 34 does not have a good

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1 S/N ratio.

The signals of the pilot channels transmitted by the base stations 22 through 24 serve as interference signals with respect to the signal of the traffic channel processed by the traffic channel receive unit 35 of the mobile station 25. That is, the mobile station 25 always receives the signals of the pilot channels transmitted by the base stations 22 through 24 to which the mobile station 25 does not belong, and thus always receives interference by the base stations 22 through 24. Hence, the given frequency range can accommodate only a reduced number of stations (corresponding to a channel capacitance).

15 SUMMARY OF THE INVENTION

It is a general object of the present invention to eliminate the above disadvantages.

A specific object of the present invention is to provide a CDMA transmitter and a CDMA receiver which can realize a CDMA mobile communication system in which an interference by signals transmitted via pilot channels by base stations is eliminated and an increased channel capacity and an improved S/N ratio can be obtained.

25 Another object of the present invention is to provide such a CDMA mobile communication system and a CDMA mobile communication method employed in the system.

The above objects of the present invention are achieved by a transmitter used in a CDMA mobile communication system comprising: a pilot channel transmit unit which intermittently transmits a pilot signal in a spread spectrum formation; and traffic channel transmit units which respectively transmit data signals in respective traffic channels.

The transmitter may be configured so that the pilot channel transmit unit comprises: a pilot

1 data generator which generates pilot data; a first  
modulator which modulates the pilot data; a second  
modulator which spreads a spectrum of modulated pilot  
data from the first modulator to thereby generate the  
5 pilot signal; and a timing generator which generates a  
timing signal applied to at least one of the pilot  
data generator and the first and second modulators so  
that the pilot signal can be intermittently  
transmitted.

10 The transmitter may be configured so that  
the pilot signal has a period shorter than an interval  
at which the pilot signal is intermittently  
transmitted.

15 The above objects of the present invention  
are also achieved by a receiver used in a CDMA mobile  
communication system comprising: a pilot channel  
receive unit which demodulates pilot signals  
respectively transmitted intermittently in a spread  
spectrum formation by transmitters and detects, from  
20 the pilot signals, a timing for a traffic channel  
demodulation; and a traffic channel receive unit which  
demodulates data at the timing detected by the pilot  
channel receive unit.

25 The receiver may be configured so that the  
pilot channel receive unit detects the timing for the  
traffic channel demodulation by comparing peaks of the  
pilot signals intermittently transmitted, the timing  
for the traffic channel demodulation corresponding to  
a greatest one of the peaks.

30 The receiver may be configured so that it  
further comprises an estimating unit which estimates  
states of paths from the pilot signals intermittently  
transmitted.

35 The receiver may be configured so that the  
estimating unit supplies the traffic channel receive  
unit with information necessary to the traffic channel  
demodulation and based on an estimated state of the

The above objects of the present invention are also achieved by a CDMA mobile communication

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1 method comprising the steps of: a) transmitting, on  
transmit sides, pilot signals in a spread spectrum  
formation; b) demodulating, on a receive side, the  
pilot signals respectively transmitted intermittently;  
5 and c) detecting, on the receive side, from the pilot  
signals, a timing for a traffic channel demodulation.

The CDMA mobile communication method may be  
configured so that the step a) comprises the step of  
intermittently transmitting the pilot signals with  
10 time offsets.

The CDMA mobile communication method may be  
configured so that the step a) intermittently  
transmits the pilot signals with the time offsets so  
that the pilot signals are serially transmitted one by  
15 one.

The CDMA mobile communication method may be  
configured so that the step a) intermittently transmit  
the pilot signals with the time offsets so that only  
one of the pilot signals is transmitted at any time.

20 The CDMA mobile communication method may be  
configured so that the step a) intermittently  
transmits the pilot signals with the time offsets so  
that a time period is provided during which none of  
the pilot signals are transmitted.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of  
the present invention will become apparent from the  
following detailed description when read in  
30 conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram of a spread  
spectrum communication transmitter used in a  
conventional CDMA mobile communication system;

35 Fig. 2 is a block diagram of a spread  
spectrum communication receiver used in the  
conventional CDMA mobile communication system;

Fig. 3 is a diagram showing transmissions in

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1 a pilot channel and traffic channels in the  
conventional system;

Fig. 4 is a diagram of a cell arrangement;

5 Fig. 5 is a diagram showing transmissions of  
pilot signals in the cells in the conventional system;

Figs. 6A, 6B, 6C and 6D are waveform  
diagrams showing correlations obtained after a  
despreading process in the conventional system;

10 Fig. 7 is a block diagram of a spread  
spectrum communication transmitter used in a CDMA  
mobile communication system according to a first  
embodiment of the present invention;

15 Fig. 8 is a diagram showing transmissions in  
a pilot channel and traffic channels in the system  
according to the first embodiment of the present  
invention;

Fig. 9 is a diagram showing transmissions of  
pilot signals in cells in the system according to the  
first embodiment of the present invention;

20 Fig. 10 is a block diagram of a spread  
spectrum communication receiver used in the system  
according to the first embodiment of the present  
invention;

*a* Figs. 11A, 11B, 11C, ~~and~~ *and 11E* 11D are waveform  
25 diagrams showing correlations obtained after a  
despreading process in the system according to the  
first embodiment of the present invention;

30 Fig. 12 is a flowchart of an operation of  
the spread spectrum communication receiver shown in  
Fig. 10;

Fig. 13 is a block diagram of a spread  
spectrum communication transmitter according to a  
second embodiment of the present invention;

35 Fig. 14 is a block diagram of a propagation  
path state estimating unit shown in Fig. 13;

Figs. 15A, 15B and 15C are diagrams of  
despread output signals; and

## 5 DETAILED DESCRIPTION

The transmitter shown in Fig. 7 includes a pilot channel transmit unit 40, and n traffic channel transmit units  $41_1, 41_2, \dots, \text{and } 41_n$ , which communicate with the first, second,  $\dots$ , and nth mobile stations. The pilot channel transmit unit 40 includes a pilot transmission timing generator 50 in addition to the aforementioned pilot data generator 1, the information modulator 2 and the spread spectrum modulator 3. The pilot transmission timing generator 50 generates a pilot transmission timing signal, which is applied to the pilot data generator 1, the information modulator 2 and the spread spectrum modulator 3. In this regard, the pilot channel transmit unit 40 shown in Fig. 7 differs from that shown in Fig. 1.

The pilot transmission timing signal controls the pilot data generator 1, the information modulator 2 and the spread spectrum modulator 3 so that the pilot signal is intermittently transmitted. This will be described later with reference to Fig. 9.

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1 spread spectrum modulator 5. The transmit data 4 is  
subjected to an error correction encoding process by  
the error correction encoder 51, and is then subjected  
to an interleaving process by the interleave unit 52.  
5 The output signal of the interleave signal is  
modulated by the information modulator 2. The output  
signal of the information modulator 2 is subjected to  
the spectrum spreading process by the spread spectrum  
modulator 5. The modulated signals generated by the  
10 pilot channel transmit unit 40 and the traffic channel  
transmit units  $41_1$  through  $41_n$  are combined by a  
combiner 53. The error correction encoder 51 and the  
interleave unit 52 are also employed in Fig. 1, but  
are not shown for the sake of simplicity.

15 A combined signal thus produced passes  
through a band limiter 54, a frequency converter 55,  
and a power amplifier 56, and is transmitted via an  
antenna 57.

Fig. 8 is a timing chart of an operation of  
20 the transmitter shown in Fig. 7. The pilot channel  
transmit unit 40 intermittently transmits the pilot  
signal at an interval  $\tau$ . One cycle of the spreading  
code for the pilot channel is completed in the period  
during which the pilot signal is transmitted. The  
25 cycle of the spreading code for the pilot channel is  
shorter than the transmission interval  $\tau$  of the pilot  
signal. The above intermittent transmission of the  
pilot signal is controlled by the pilot transmission  
timing signal generated by the generator 50. During  
30 the interval between two consecutive pilot signals,  
only the traffic channel signals are transmitted.

When the base stations 21 through 24 shown  
in Fig. 4 have transmitters configured as shown in  
Fig. 7, the transmitters of the base stations 21  
35 through 24 transmit respective pilot signals, as shown  
in Fig. 9. The base stations 21 through 24  
intermittently transmit the pilot signals at the

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1 intervals  $\tau$ , and start to transmit them at different  
timings corresponding to respective inherent time  
offsets so that a plurality of base stations  
simultaneously transmit the respective pilot signals.

5 In the case shown in Fig. 9, sections TS are  
provided in which none of the base stations transmit  
the respective pilot signals. When the sections TS  
are set longer than the delay time of the multipath,  
it is possible to prevent a delay wave of the pilot  
10 signal transmitted by a base station and propagated  
through the multipath from overlapping with the pilot  
signal next transmitted by another base station. If  
the distances between the base stations are short and  
there are short delay times, as in the case of a radio  
15 LAN system, it will be not necessary to provide the  
time sections TS.

Fig. 10 is a block diagram of a spread  
spectrum communication receiver used in the CDMA  
mobile communication system according the first  
20 embodiment of the present invention. In Fig. 10,  
parts that are the same as those shown in the  
previously described figures are given the same  
reference numbers. The receiver shown in Fig. 10  
includes an antenna 61, an amplifier 62, a frequency  
25 converter 63, a band limiter 64, a pilot channel  
receive unit 44 and a traffic channel receive unit 45.

The pilot channel receive unit 44 includes a  
receive level measuring unit 18, a hand-over  
controller 19 and a timing regenerator 65. The  
30 despreader 8 performs the despreading process on the  
received signal by using the spreading code for the  
pilot channel. The path detector 11 detects the paths  
of the received signal having respective delay times.  
The timing regenerator 65 regenerates a timing signal  
35 indicative of the beginning of the pilot signal  
transmission interval  $\tau$  by using the output signal of  
the path detector 11. The hand-over controller 19

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1 performs the hand-over process by using the output  
signal of the path detector 11 and the timing signal  
regenerated by the timing regenerator 65. The receive  
level measuring unit 18 measures the receive power  
5 level of the detected path at the timing indicated by  
the timing signal.

A further description of the pilot channel  
receive unit 44 will be given with reference to Figs.  
11A through 11E.

10 The path detector 11 detects peaks of the  
pilot signals in sections A, B, C and D shown in Fig.  
11E, which corresponds to the offset times between the  
base stations 21, 22, 23 and 24 shown in Fig. 4. The  
path detector 11 detects peaks 201, 202, 203 and 204  
15 in the sections A, B, C and D, respectively, and  
compares them with each other in order to select the  
greatest peak from among them. In the case shown in  
Fig. 4, the mobile station 25 is closet to the base  
station 21, and the peak 201 is greater than the peaks  
20 202, 203 and 204. The traffic channel receive unit 45  
shown in Fig. 10 operates based on the greatest peak  
201. The timing regenerator 65 regenerates the timing  
signal from the timing of the greatest peak 201. The  
pilot signal transmission interval  $\tau$  of each base  
25 station is known. Hence, it is possible to estimate  
the next pilot signal transmission time from the  
timing of the peak 201 transmitted by the base station  
21. In this manner, the timing signal can be  
reproduced.

30 The hand-over controller 19 performs the  
hand-over control when the path detector 11 detects  
the greatest peak from another base station. In  
response to the timing signal based on the timing of  
the greatest peak of another base station, the hand-  
35 over control is carried out. The receive level  
measuring unit 18 measures the receive power level of  
the greatest peak and thus determines a transmit power

1 level of the mobile station 25.

Turning to Fig. 10 again, the traffic  
channel receive unit 45 includes the despreaders 9,  
and 10, the RAKE combiner 12, the information  
5 demodulator 13, a deinterleave unit 66 and an error  
correction decoder 67. The deinterleave unit 66  
performs a deinterleaving operation on the demodulated  
signal from the information demodulator 13. The error  
correction decoder 67 performs an error correction and  
10 decoding process on the output signal of the  
deinterleave unit 66.

Fig. 12 is a flowchart of an operation of  
the spread spectrum communication receiver shown in  
Fig. 10 according to the first embodiment of the  
15 present invention.

At step S11, the despreaders 8 despreads the  
received signal by using the spreading code for the  
pilot channel. At step S12, the path detector 11  
detects the greatest peak (the peak having the  
20 greatest amplitude) as has been described previously.  
At this time, peaks propagated through some delayed  
paths following the greatest peak are also detected  
for the RAKE combine process, and timing information  
concerning these peaks is applied to the traffic  
25 channel receive unit 45, as indicated by a broken  
arrow in Fig. 12. At step S13, the timing regenerator  
65 regenerates the timing signal, as has been  
described previously. At step S14, the receive level  
measuring unit 18 measures the receive power levels of  
30 the peaks detected by the path detector 11.

At step S15, the path detector 11 detects  
that the greatest peak is transmitted by a base  
station other than the base station currently  
identified. Thus, the hand-over control is started at  
35 step S16, and the timing regenerator 65 starts to  
regenerate the timing signal based on the peak  
detected by step S15, at step S17. At this step, the

1 timing information concerning the peak detected at  
step S15 is supplied to the traffic channel receive  
unit 45.

5 The despreaders 9 and 10 of the traffic  
channel receive unit 45 despread the received signal  
by the spreading codes with an offset time at step  
S21. For example, the despreader 9 despreads the  
received signal at the timing when the greatest peak  
is detected by the path detector 11, and the  
10 despreader 10 despreads the received signal with an  
offset time corresponding to a delay time of the  
second greatest peak detected by the path detector 11.  
At step S22, the RAKE combiner 12 combines the  
despread received signals by the RAKE combine process.  
15 At step S23, the information demodulator 13  
demodulates the RAKE-combined signal. Then, the  
deinterleaving process and the error-correction coding  
process are successively carried out.

20 According to the first embodiment of the  
present invention, the following advantages can be  
obtained. The output signal of the despreader 8 has  
the signals shown in Figs. 11A through 11D  
superimposed. At the pilot signal transmission timing  
of the base station 21 to which the mobile station 25  
25 belongs, the other base stations 22, 23 and 24 do not  
transmit the pilot signals. Hence, at the pilot  
signal transmission timing of the base station, the  
pilot signals of the base stations 22, 23 and 24 to  
which the mobile station 25 does not belong are not  
30 superimposed and no noise is added to the pilot signal  
transmitted by the base station 21. Hence, a high S/N  
ratio can be obtained.

35 All the base stations 21 through 24  
intermittently transmit the pilot signals at the  
different timings. Hence, the traffic channel receive  
unit 45 of the mobile station 25 receives interference  
signals for a short time, as compared to the prior art

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1 in which all the base stations continue to transmit  
the pilot signals. As a result, an increased number  
of stations in the same frequency band can be  
accommodated. In other words, the channel capacity  
5 can be increased.

The spreading code which has one period in  
the pilot signal transmission interval  $\tau$  is used in  
the spread spectrum modulator 3 shown in Fig. 7.  
Alternatively, it is possible to use a spreading code  
10 that has a plurality of periods in the pilot signal  
transmission interval  $\tau$ . Even in this case, the same  
effects as those obtained when the spreading code  
having one period in the interval  $\tau$  can be obtained.  
It is also possible to use a spreading code having a  
15 period longer than the pilot signal transmission  
interval  $\tau$ . In this case, a part of the spreading  
code is transmitted in the pilot signal transmission  
interval  $\tau$ . Even in this case, the same effects as  
those obtained when the spreading code having one  
20 period in the interval  $\tau$  can be obtained.

In the above description of the first  
embodiment of the present invention, the base stations  
transmit the pilot signals, and the mobile stations  
receive them. However, the concept of the first  
25 embodiment of the present invention can be applied to  
a structure in which the mobile stations transmit  
signals such as pilot signals and the base stations  
receive these signals.

The above description of the first  
30 embodiment of the present invention is directed to use  
of four cells. However, the same effects as those  
obtained in the case of four cells can be obtained  
even when a different number of cells are used.

When a small number of cells are provided,  
35 it is possible to realize an arrangement in which,  
when one base station transmits the pilot signal, the  
other base stations do not transmit the pilot signals.

1 If a large number of cells are provided, it may be  
difficult to realize the above arrangement. In this  
case, a plurality of base stations are allowed to  
simultaneously transmit the pilot signals under a  
5 condition that these base stations are sufficiently  
away from each other and the mobile station located  
therebetween receives sufficiently attenuated pilot  
signals therefrom due to propagation-based  
attenuation.

10 In the aforementioned description, the time  
sections TS are provided as shown in Fig. 9, during  
which none of the base stations transmit the pilot  
signals. However, the time sections TS are completely  
or partially omitted.

15 In the aforementioned description, the pilot  
transmission timing signal is applied to the units 1,  
2 and 3, as shown in Fig. 7. However, it is possible  
to modify the structure shown in Fig. 7 so that the  
pilot transmission timing signal is applied to only  
20 one or two of the units 1, 2 and 3 to thereby  
intermittently transmit the pilot signal.

A description will now be given of a second  
embodiment of the present invention.

25 Fig. 13 is a block diagram of a spread  
spectrum communication receiver according to the  
second embodiment of the present invention. In Fig.  
13, parts that are the same as those shown in the  
previously described figures are given the same  
reference numbers. The receiver shown in Fig. 13 has  
30 a pilot channel receive unit 44A in which a  
propagation path state estimating unit 17 is provided.  
The propagation path state estimating unit 17  
estimates the state of the propagation path by using  
the pilot signals intermittently transmitted.

35 Fig. 14 shows a structure of the propagation  
path state estimating unit 17. As shown in Fig. 14,  
the unit 17 includes a fading variation measuring part

1     250 and a fading variation estimating part 251  
receiving an output signal of the fading variation  
measuring part 250.

5     In the actual mobile communication systems,  
a radio wave propagated through a transmission path is  
affected by multipath fading and Rayleigh fading.

10     Figs. 15A through 15C show examples of the  
despread output signals. In these figures, the  
signals transmitted by the base station 21 to which  
the mobile station 25 belongs are shown. Further,  
vectors are used to indicate the peak points  
(locations) and magnitudes of the correlation waveform  
necessary for the demodulating process. A reference  
number 101 indicates an orthogonal axis and a  
15     reference number 102 indicates an in-phase axis.  
Further, a reference number 103 denotes a time axis.

20     Fig. 15A shows the despread output signal  
which has not been affected by fading variation. A  
vector 104 indicates the amplitude and phase of each  
peak 201 shown in Fig. 11A. Fig. 15B shows the  
despread output signal which has been affected by  
Rayleigh fading so that the amplitude and phase of a  
vector 105 are varied with time. The amplitude and  
phase of the vector 105 are varied due to the state of  
25     the propagation path. Fig. 15C shows the despread  
output signal which has been affected by two-wave  
multipath fading. A reference number 106 indicates a  
leading wave, and a reference number 107 indicates a  
delayed wave. The amplitudes and phases of both of  
30     the waves 106 and 107 are varied.

35     The pilot signal transmitted by the base  
station 21 is known data. Hence, the despread output  
waveform of the pilot signal transmitted by the base  
station 21 without being affected by any fading (Fig.  
15A) is also known for the mobile station 25. Hence,  
it is possible to estimate, in the mobile station 25,  
variations (Figs. 15B and 15C) in the amplitude and

1 phase of the pilot signal affected by fading during  
propagation as well as the difference between the  
leading wave and the delayed wave by comparing the  
despread output waveform without being affected by  
5 fading and the despread output waveform affected by  
fading.

As has been described previously, the pilot  
signal is intermittently transmitted by each of the  
base stations with time offsets. Hence, the  
10 magnitudes of variations in the amplitude and phase of  
the pilot signal caused by fading and measured by the  
fading variation measuring part 250 shown in Fig. 14  
correspond to data obtained by sampling the pilot  
signal at intervals  $\tau$ . Hence, the fading variation  
15 estimating part 251 interpolate the sampled data  
output by the fading variation measuring part 250, and  
thus estimates fading variations in each pilot signal  
transmission interval with respect to the same base  
station.

20 Fig. 16 shows estimated results output by  
the fading estimating part 251. The fading variation  
estimating part 251 outputs an estimated fading  
variation 108 of the leading wave and an estimated  
fading variation 109 of the delayed wave. These  
25 estimated variations 108 and 109 are used to determine  
the timings at which the despreader 9 and 10 start to  
despread the received signal and weight coefficients  
for the RAKE combine process carried out by the RAKE  
combiner 12.

30 In the aforementioned first embodiment of  
the present invention, the RAKE combine is carried out  
by using the information concerning the phase,  
amplitude and timing of the pilot signal that is  
intermittently transmitted. Hence, the RAKE combine  
35 carried out during the time when the pilot signal is  
not received employs the information obtained when the  
pilot signal is actually received. On the other hand,

1 according to the second embodiment, variations in the  
despread output signal during the time when the pilot  
signal is not received are estimated as described  
above. Thus, the RAKE combine in the second  
5 embodiment of the present invention uses the estimated  
results 108 and 109 and the received signal of the  
traffic channel. Hence, the performance of the  
receiver according to the second embodiment of the  
present invention can be further improved.

10 The receive level measuring unit 18 shown in  
Fig. 13 can determine the receive power level taking  
into account an influence of fading. Hence, the  
transmission power can be determined more precisely.  
The hand-over controller 19 also utilizes the  
15 variations due to fading, and can perform the take-  
over process more precisely.

The present invention is not limited to the  
specifically disclosed embodiments, and variations and  
modifications may be made without departing from the  
20 scope of the present invention.

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